A GOLF CLUB SHAFT FORMED FROM METAL-CONTAINING PREPREG AND NON-METAL FIBER PREPREG AND METHOD OF MAKING THE SAME

Field of the Invention

The present invention relates generally to golf club shafts and, more particularly, to a golf club shaft formed from metal-containing prepreg and non-metal fiber prepreg and method of making the same.

Background of the Related Art

The known golf club shafts may generally be regarded as metallic and non-metallic. Golf club shafts of metallic construction are commonly manufactured in tubular form using alloys such as steel. The materials and methods of manufacture vary, but all such shafts will hereafter be referred to as "steel shafts."

Golf club shafts of non-metallic construction are commonly manufactured in a sheet-wound manner using "prepreg" comprising non-metallic fibers such as carbon fibers, boron fibers, glass fibers, aramid fibers, and so on, that are pre-impregnated with a heat curable resin such as thermoset epoxy resin. The golf club shafts are made by wrapping the prepreg onto a tapered mandrel, wrapping the prepreg that was previously layered onto the mandrel in a binding tape, heating the overall assembly to cure the resin in the prepreg, removing the binding tape, and then removing the mandrel to leave a shaft that is nearly ready for insertion into a gold club head. Non-metallic shafts of this nature

will sometimes hereafter be referred to as "carbon shafts," but the latter term is intended to include non-metallic shafts of other sheet-wound construction including, but not limited to, glass.

Although steel shafts have been used longer, carbon shafts have become very popular for golf clubs known as "woods." Steel shafts, however, have not gained as much popularity for golf clubs known as "irons."

Carbon shafts are easily made light in weight as compared to steel shafts. Moreover, the bending strength and distribution characteristics of carbon shafts can be freely altered through the design variations. Because of these beneficial characteristics, many types of carbon shafts have been developed and widely used by many players. Still, carbon shafts remain unpopular for use with irons, even though they are very popular with both average and advanced players for woods. This is particularly notable among the advance golf players where, it appears, that steel shafts are becoming more and more popular every year for use with irons.

There have been numerous research and development efforts to use the variable design characteristics of carbon shafts to develop carbon shafts that are superior to steel shafts for use with irons, but this has not yet been achieved.

There remains a need, therefore, for a golf club shaft of sheet-wound construction that more closely approximates the desirable characteristics of a steel shaft.

SUMMARY OF THE INVENTION

The invention may be regarded as a golf club shaft formed by winding a plurality of layers around a mandrel that is removed after curing comprising: a layer of metal-containing prepreg wrapped at a tip of the shaft; and a layer of non-metal fiber prepreg wrapped adjacent to the layer of metal-containing prepreg throughout a length of the shaft.

The invention may also be regarded as a method of making a golf club shaft comprising the steps of: providing a mandrel that tapers from a butt end to a tip end; wrapping a layer of metal-containing prepreg around the mandrel from the tip end thereof toward and toward but not all the way to the butt end thereof; wrapping a layer of non-metal fiber prepreg adjacent to the layer of metal-containing prepreg from the tip end thereof all the way to the butt end thereof; curing the prepreg; and removing the mandrel from the prepreg.

BRIEF DESCRIPTION OF THE DRAWINGS

The just summarized invention can be best understood with reference to the following description taken in view of the drawings of which:

Figure 1 is a table showing the length, overall mass, and center of mass location of several representative golf club shafts that are commonly used for a complete set of irons.

Figure 2 is a cross-sectional view of a metal-containing prepreg 110 that contains a metal fiber layer 112;

Figure 3 is a cross-sectional view of a metal-containing prepreg 210 that contains a metal powder layer 215;

Figure 4 is a table of the preferred metal used in the metal-containing prepreg;

Figure 5 is a longitudinal section of a first preferred golf club shaft 30 according to a first embodiment of the invention that includes a first metal-containing prepreg layer 7 that extends part way from the tip;

Figure 6 is longitudinal section of the first preferred golf club shaft 30 of Figure 5 as it is being made around a mandrel 13;

Figure 7 is a diagram showing the prepreg components that are used in manufacturing the first preferred golf club shaft 30 of Figure 5;

Figure 8 is a longitudinal section of a second preferred golf club shaft 40 according to a second embodiment of the invention that includes the first metal-containing prepreg layer 7 and an second metal-containing prepreg layer 7a that extends beyond the first layer 7;

Figure 9 is longitudinal section of the second preferred golf club shaft 40 of Figure 8 as it is being made around a mandrel 13;

Figure 10 is a diagram showing the prepreg components that are used in manufacturing the second preferred golf club shaft 40 of Figure 8, including an additional component 1a that is used form layer 7a;

Figure 11 is a table compiling the results of several examples of golf club shafts made according to this invention, several comparison examples, and some reference examples;

Figure 12 is a table compiling the results of a field test involving a number 5 iron made with each of the shafts referenced in the table of Figure 11;

Figure 13 is a diagram illustrating a method of measuring the elasticity index (IE) value of a golf club shaft; and

Figure 14(a) and 14(b) are diagrams illustrating a method of measuring a golf club's toe down where Figure 14(a) indicates the golf club while addressing the ball (not shown) and Figure 14(b) indicates the golf club upon impacting the ball.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is directed to providing a carbon shaft that is superior to a steel shaft for use with golf club irons. Carbon shafts are generally lighter than steel shafts such that a player can theoretically swing an iron with higher velocity and hit the ball farther if the iron had a carbon shaft rather than a steel shaft. Nonetheless, to date, advanced players tend to use steel shafts rather than carbon shafts with their irons. The inventor has concluded that the advanced players prefer steel shafts for their irons because the lighter carbon shafts are easily subject to over swing that reduces the distance the ball travels. The major problem with carbon shafts, in other words, is the lack of stability in distance hit. The inventor, therefore, has analyzed the factors relating to this instability problem, has made certain observations, and has come to certain conclusions.

Figure 1, in particular, is a table showing the length, overall mass, and center of mass location of several representative golf club shafts that are commonly used for a complete set of irons. As shown, the commonly used steel shafts weigh more than 100 g, and they have a center of mass (balance point) that is located at about 50% of the overall length of the shaft, measured from the tip of the shaft, as compared to 53% for carbon shafts. Because the center of gravity in a steel shaft is located closer to the tip of the shaft, a golf club with a typical steel shaft can achieve a similar swing balance using a less massive head than with a typical carbon shaft. A golf club with a steel shaft, therefore, has reduced toe down at impact that provides more consistency to the ball's

trajectory. As the result, an iron with a steel shaft tends to stabilize the distance and the direction of the ball that is hit relative to an iron with a carbon shaft.

The goal here is to achieve similar characteristics with a sheet-wound shaft. As noted in the background section above, carbon shafts are usually manufactured by a sheet winding method involving the steps of: (1) providing a mandrel that is circular in cross section, has a diameter that decreases as it gets closer to the tip, and is usually longer than the shaft to be formed on the mandrel; (2) winding non-metal fiber prepreg around the mandrel to form layers of prepreg along the length of the mandrel; (3) heat curing the prepreg that was wrapped around the mandrel from both inside and outside to make a complete shaft; and (4) extracting the mandrel from the butt end of the shaft to leave a shaft that is hollow throughout its length.

One way to make a carbon shaft's center of gravity positioned like a steel shaft's center of gravity is to simply increase the weight at the tip of the shaft by increasing the number of layers wrapped around the tip of the mandrel. Unfortunately, however, the tip of a carbon shaft made according to this method will be so stiff that it alters the kick point of the shaft and detrimentally affects the hitting characteristics of the shaft.

A golf club shaft made according to the preferred embodiment of this invention, however, solves the above said problem of carbon shafts in order to provide a golf club iron that exhibits consistent distance and direction

A golf club shaft made according to the preferred embodiment of this invention is formed by wrapping the non-metal fiber prepreg around the

mandrel and heat curing the prepreg from both inside and out in order to provide a carbon shaft that has an EI value of $3.0 \sim 4.5\ kgf \circ m^2$ at 200 mm from the tip as calculated from the following equation (see Figure 13):

$$EI = \frac{1}{48} \circ \frac{WL^3}{\delta}$$

where

δ = Amount of Bend (mm)

W Load (20kg)

L = Center Length (300mm)

and also by wrapping a relatively massive metal-containing prepreg closer to the tip of the golf club shaft to make its overall mass about 80~130 g and to locate the shaft's center of mass to about 45~51% of the overall length of the shaft from the tip.

The metal-Containing Prepreg

The metal-containing prepreg that is wrapped around a mandrel in the process of forming a golf club shaft according to this invention may be provided in a number of embodiments. Figures 2 and 3, for example, show two different metal-containing prepregs. Figure 2 is a cross-sectional view of a "metal fiber" prepreg 110. Figure 3 is a cross-sectional view of a "metal powder" prepreg 210. Other version, of course, are possible.

The metal fiber prepreg 110 of Figure 2 comprises a metal fiber layer 112 that is sandwiched between two non-metal prepreg layers 113, 113. The metal fiber layer 112 contains metal fibers 2. The metal powder prepreg 210

of Figure 3 comprises a metal powder layer 215 that is sandwiched between two non-metal prepreg layers 213, 213. The metal power layer 215 contains a metal powder 5 that is dispersed in a synthetic resin sheet 6.

Figure 4 is a table of the preferred metals. As shown, the preferred metal fiber 2 has a specific mass of more than 7 g/cm^3 and high tensile strength. The preferred metal powder 5 similarly has a specific mass of more than 7 g/cm^3.

The non-metal fiber prepreg layers 113, 113 and 213, 213 can be of the same kind or different kinds (as shown). In alternative embodiments, the metal fiber layer 112 or metal powder layer 215 are bound to only one non-metal fiber prepreg layer 113 or 213.

In a preferred embodiment of the invention, a metal-containing prepreg (e.g. a metal fiber prepreg 110 or metal powder prepreg 210) is wound around the inner layers of the shaft closer to the tip of the shaft and then, after that, non-metal fiber prepreg is wrapped on top of the metal-containing prepreg throughout the length of the shaft. The metal-containing prepreg does not have much effect on the specification and characteristic of the shaft even though it contains metal. In other words, the metal-containing prepreg will increase the overall mass of the shaft without altering the characteristic and the specification of the shaft. It is also possible to wind the metal-containing prepreg in the mid-layer and/or the outer layer. When the metal-containing prepreg is wrapped onto such multiple locations, it is desirable to wind an inner layer of non-metal fiber prepreg onto the shaft at least once before winding on the additional layers of

metal-containing prepreg. When the metal-containing prepreg is rolled onto the inner layer, it is desirable to roll it within 40% of the overall length of the shaft from the tip. However, when the metal-containing prepreg is wrapped onto the other locations, it is not necessary to remain near the tip.

In order to manufacture a shaft with a metal-containing prepreg located at least in one location closer to the tip by sheet winding method, the metal-containing prepreg must first be wound around the mandrel closer to the tip from the center of the shaft, and the non-metal fiber prepreg must secondly be wrapped around the entire length of the shaft which is then heat cured. After heat-curing, the shaft is cooled, and the mandrel is extracted from its base. However, if the mandrel's cross section tapers off constantly along its central axis, then the area where the metal-containing prepreg is wound around will increase the diameter at a particular area, protrude, and appear unsightly. Therefore, the preferred mandrel's cross section diameter must be made smaller in this particular area to accommodate the metal-containing prepreg in an annular recess 12. After the metal-containing prepreg is wound the mandrel within the annular recess 12, the outer diameter of the metal-containing prepreg tapers off constantly along the axis of the mandrel.

As just explained, the tip of the mandrel is made progressively thinner in order to define an annular recess 12 that accommodates the metal-containing prepreg. This area is likely to be the shaft's weak spot when the shaft is flexed because the strengths of the metal-containing prepreg and the non-metal fiber prepreg are different, and because the weight of the

metal-containing prepreg can concentrate the force on this weak spot. This may lead to a breakage in the shaft. Therefore, the tapering angle of the mandrel at this location where the metal-containing prepreg is wrapped around must be made bigger so that the thickness of the metal-containing prepreg will decrease as it gets closer to the butt end of this prepreg.

In this invention, the metal-containing prepreg's strength is inferior to that of non-metal fiber prepreg and the metal-containing prepreg is more massive than the non-metal fiber prepreg such that it will not greatly increase the tip strength compared to the shafts that are entirely made of non-metal fiber prepreg. The metal-containing prepreg is inserted into a location that is closer to the tip of the shaft compared to the center of the shaft. This will move the center of the mass to about 45~51% of the overall length of the shaft from the tip. The metal-containing prepreg will also increase the EI value from $2.5 \sim 3.5\ kgf \circ m^2$ to $3.0 \sim 4.5\ kgf \circ m^2$ and make the shaft's overall mass 80~130 g such that the center of mass and the strength are very close to the value of a typical steel shaft. The shaft, therefore, will closely approximate the characteristic of a steel shaft even though it is predominantly a carbon shaft of sheet-wound construction. It will stabilize the orbit of the ball because the toe down that occurs from shaft distortion while swinging is very similar to that of a steel shaft. The EI value that represents the strength of the shaft is measured at 200 mm from the tip because the strength at this location greatly affects the toe down. The EI value is set at $3.0 \sim 4.5\ kgf \circ m^2$ because less than $3.0 kgf \circ m^2$ is so flexible that the amount of toe down will increase and cause destabilization, and because more than

$4.5\,kgf \circ m^2$ is so stiff that the hitting feeling will worsen. The EI value measurements are based on the distance of flex (mm) δ, central load (20 kg) W, and the loading distance (300 mm) L that are indicated in Figure 9.

If the center of mass is less than 45% of the overall length of the shaft from the tip, in order to set the swing balance to be the same as that of steel shaft golf club, the mass of the head must be reduced considerably. Therefore the head can not retain the momentum, and this results in destabilization of swing orbit. This will also destabilize the distance and the direction of ball. On the other hand, if the center of mass is more than 51% of the overall length of the shaft from the tip, then it would be exactly as same as the non metal shafts. The shafts that contain the metal-containing prepreg will also be heavier in its overall mass such that the mass per unit length will also increase. The distribution of the mass, therefore, is greater at the tip and the butt area of the shaft and is lesser in the mid-section of the shaft just like a steel shaft. If the mass distribution of the shaft in the mid-section is also as great as the rest of the shaft, then the mid-section of the shaft becomes stiff also. This will increase the shaft's overall stiffness, and the shaft will no longer can exhibit its characteristic flex and stiffness of a carbon shaft. The mass of the shaft and the EI value and the mass of the shaft may be adjusted by varying the type of metal-containing prepreg, its mass, thickness, and the number of prepreg plies,. The mass of the shaft is preferably adjusted to 80~130g in order to have the same type of swing feeling as steel shafts. If the mass of the shaft is less than 80g, the head speed of the golf club shaft can be increased, but it can't stabilize

the speed, because it is simply too light. However, when the weight is more than 80g, the EI value will be $3.0 \sim 4.5\ kgf \circ m^2$. If the center of mass is at least 45~51% of the overall length of the shaft from the tip, the shaft can be said to have an ideal characteristic as described previously. On the other hand, if the shaft is more massive than 130g , the swing speed can not be increased and a long distance can not be reached. The preferred mass of the shaft is about 120g, the typical mass of an ordinary steel shaft.

The benefits of this invention are evident from the following examples that are described in relation to Figures 5-10:

Application Example #1

Figures 5-7 relate to a first application example. Figure 5 is a cross-sectional view of a first preferred shaft 30 made according to this invention. The overall length is 975 mm. The shaft 30 is formed from a layer 7 of metal-containing prepreg that extends about 280 mm from the tip, a layer 8 of non-metal fiber prepreg that extends throughout its length, an auxiliary layer 9 of non-metal fiber prepreg located only at the tip. The metal-containing prepreg layer 7 protrudes inward from the inner side of the cylindrical shaped layers of non-metal fiber prepreg 8, but the thickness of the metal-containing prepreg 7 gets thinner as it gets closer to the butt section of the shaft 30 such that it is shaped like a chock. The non-metal fiber prepreg layers 8 also taper off closer to

the tip, the inner layer being a bias layer 10, and the outer layer being a straight layer 11.

Sub B1 Figure 6 shows the preferred mandrel 13 used to make a shaft according to this invention. The mandrel 13 is tapered off more than an ordinary mandrel near the tip to provide a recess 12 that accommodates the metal-containing prepreg layer 7. The metal-containing prepreg 7 is rolled around the recess 12 until it covers the recess 12 such that the then-formed subassembly has a constant tapering as indicated in Figure 6.

Figure 7 shows the various prepreg components used to make the shaft 30 of Figure 5. The components include a metal-containing prepreg 1; a pair of bias ply carbon fiber prepregs 14, 14a; three straight ply carbon fiber prepregs 15, 15a, 15a; and a straight ply carbon fiber prepreg 15c. The metal-containing prepreg 1 is a metal fiber prepreg that includes metal fiber 2 as shown in Figure 2. The preferred metal fiber 2 is a stainless steel fiber (outside diameter 100 μm, pitch width of 0.5 mm) and the metal fiber 2 is sandwiched between a carbon fiber prepreg 113 (the resin is the epoxy resin) on the outside and a glass fiber prepreg 113 (the resin is epoxy resin) on the inside. The metal fiber prepreg 1 is shorter than the recess 12 and it has a diagonal cut at the base so that it will taper off smoothly when rolled around the mandrel 13 in the recess 12.

The non-metal fiber prepreg layer 8 is formed by rolling the two bias ply carbon fiber prepregs (the resin is epoxy resin) 14, 14a to provide the bias layer 10 and the straight ply carbon fiber prepregs (the resin is epoxy resin) 15,

15a, 15b are then rolled on to provide straight ply layer 11. Finally, the straight play carbon fiber prepreg 15c is rolled on to provide the auxiliary layer 9. After the metal fiber prepreg 1 and the non-metal fiber prepreg 14, 14a, 15, 15a, 15b, 15c are rolled on as described, the entire assembly of the shaft 30 and the mandrel 13 is heat cured from inside out in order to make the shaft 30 . And after cooling the shaft 30, the mandrel 13 is extracted from the base. The finishing specifications of the shaft are as follow: the mass of the shaft is about 120.6 g, the center of mass is 49.4% of the overall length from the tip, and the EI value is $3.0 \sim 4.5\ kgf \circ m^2$. The EI value is calculated from the previously described equation.

Application Example #2

Figures 8-10 relate to a second application example. In this application example, metal-containing prepreg 1a whose length is 480 mm is rolled on to the mandrel 13 between the bias layer 10 and the straight layer 11 of the non-metal fiber prepreg layer 8, . The metal-containing prepreg 110a forms a metal-containing prepreg layer 7a. This shaft's mass is 120.7 g, and its center of mass is 50.1% of the overall length from the tip, and its EI value is $3.73\ kgf \circ m^2$ at 200 mm from the tip.

Figure 8 shows the cross section of the shaft 40 that is manufactured by the method shown in Figure 9 using the mandrel 13. Figure 10 shows the components and implied steps of the manufacturing procedure.

Application Example #3

In this application example, the metal fiber prepreg 110a of example #2 is replaced with a metal powder prepreg 210. This metal powder prepreg 210 contains tungsten metal powder 5 as shown in Figure 2, and the synthetic resin sheet 6 is epoxy resin. The non-metal fiber prepreg 213, 213 that is attached to the sides of the sheet 6 can be carbon fiber prepreg or glass fiber prepreg. This shaft's mass is 120.6g, and its center of mass is 50.3% of the overall length from the tip. And the EI value is $3.68\ kgf \circ m^2$ at 200 mm from the tip.

Application Example #4

In this application example, the thickness of the mandrel 13 is increased such that the amount of resin and fiber content of bias carbon fiber prepreg 14, 14a can be decreased and changed to a higher elastic modulus fiber. After increasing the number of plies at the tip and decreasing the number of plies at the base, the shaft is made lighter than the shaft in the application example 2. This shaft's mass is 105.7g, and the center of mass is 50.5% of the overall length from the tip. And the EI value is $3.74\ kgf \circ m^2$ at 200 mm from the tip.

Application Example #5

In this application example, after changing the bias carbon fiber prepreg 14, 14a to a high elastic modulus than those used in application example #4, the mass of the shaft is further reduced by rolling less number of layers of

prepreg. After this, the mass of the shaft is 96.1g, and the center of mass is 49.3% of the overall length of the shaft from the tip. And the EI value is $3.74\ kgf \circ m^2$ at 200 mm from the tip.

Comparison Example #1

In this comparison example, the mandrel 13 is changed to a mandrel that has a constant tapering throughout its length along the central axis of the mandrel, and simultaneously the metal fiber prepreg 110 is replaced with a non-metal fiber prepreg in order to make the ordinary and typical carbon shaft. This mass of this shaft is 102.7g, and its center of mass is 52.8% of the overall length of the shaft from the tip. And EI value is $3.18\ kgf \circ m^2$ at 200 mm from the tip.

Comparison Example #2

In this comparison example, when the mandrel is changed to a mandrel that has a constant tapering throughout the entire length of the mandrel, and the metal fiber prepregs 110, 110a are changed to glass fiber prepregs. This shaft's mass is 119.6g, and the center of mass is moved to 49.8% of the overall length of the shaft from the tip. The EI value was $4.90\ kgf \circ m^2$ at 200 mm from the tip.

Comparison Example #3

In this comparison example, the carbon fiber bias prepreg 14, 14a is changed to a shape that is closer to a rectangular shape, and two of the metal fiber prepregs 110a are rolled on to move the center of mass closer to the tip. The mass of this shaft is 123.1g, and the center of mass is 44.4% of the overall length of the shaft from the tip. The EI value is $4.06\ kgf \circ m^2$ at 200 mm from the tip.

Results

Figure 11 is a table that compiles the data of the shafts that are produced in the application examples 1-5 and in the comparison examples 1-3.

Figure 12 is a table of overall results after a number 5 iron was produced using each of these shafts. In particular, their balances were measured, and actual field hitting tests were performed under the conditions set below.

Clubs Used

A head weighing 246 g and a grip weighing 48 g were attached to the tip and the butt of each shaft. The overall length of each shaft was 38 inches.

Balance

The measurements were made according to the swing balance weight method that is standardized by Japanese Golf Products Association Inc.

In this method, the golf club is supported at 14 inch from the butt, and the weight that is necessary to balance this shaft at the butt is calculated. After referring to the table of comparison between the mass and the ranking of the swing balance (...,D0, D1, D3 D4, ...), the swing balance is measured. The swing balance feels lighter according to the order of alphabet and the number.

Actual Hitting Field Test

Eight players whose handicap is less than 10 and whose experiences are more than 10 years were used for field testing. The carbon shafts were evaluated using the blind test on the scale of 1 to 5 and the scores were averaged at the end.

Toe Down

A high speed camera was used to shoot from the behind the direction of the traveling ball. As indicated in Figures 14(a) and 14(b), the angle between the tangent line S at 200 mm from the hosel end and the standard line GL that is indicated on the back of the club head was measured. The angle when addressing is angle α, and the angle during impact is angle β. The amount of toe down was determined as the difference (α-β) and the average toe down value was calculated.

As described above, the golf club shaft of this invention contains a metal-containing prepreg (e.g. metal fiber or metal powder) rolled around the tip

at least once in order to make the EI value $3.0 \sim 4.5\ kgf \circ m^2$, the mass 80~130g, and the center of mass to be at 45~51% of the overall length of the shaft, such that the shaft exhibits the characteristics of the steel shaft that the advance players favor. With this shaft, a player can hit a long distance consistently with a stabilized direction. In overall, it can provide a shaft that feels well to the players.